Journal of
Entomology

ISSN 1812-5670

Academic
Journals Inc.

www.academicjournals.com

Journal of Entomology 9 (1): 41-49, 2012
ISSN 1812-5670 / DOI: 10.3923/je.2012.41.49

The Effect of Different Cereal Aphid Species on the Performance of Two Coccinellid Predators

[1]J.G. Nyaanga, [1]A.W. Kamau, [1]R.S. Pathak and [2]R.K. Tuey
[1]Department of Crops, Horticulture and Soils, Egerton University, P.O. Box 536, Egerton, Kenya
[2]Kenya Agricultural Research Institute (National Plant Breeding Centre), Private Bag, Njoro, Kenya

Corresponding Author: J.G. Nyaanga, Department of Crops, Horticulture and Soils, Egerton University, P.O. Box 536, Egerton, Kenya

ABSTRACT

Coccinellid beetles have been studied worldwide for integration with biological aphid control systems but their performance on different cereal aphid prey has not been investigated. A study was conducted to evaluate the relative suitability of five cereal aphid prey species; *Rhopalosiphum padi*, *Metopolophium dirhodum*, *Sitobion avenae*, *Schizaphis graminum* and *Diuraphis noxia* on two coccinellid predators; *Adonia variegata* and *Cheilomenes lunata*. The five aphid species were separately fed to first instar larvae and newly emerged adult coccinellids in the laboratory. Development and reproduction parameters were quantified. The duration of the immature stages of *C. lunata* was significantly shorter ($F = 1408.34$; $df = 5, 25$; $MSE = 0.3$; $p<0.0001$) on *R. padi* (11.7±0.14) and longest on *D. noxia* (16.2±0.07). The duration for *A. variegata* larvae was similarly shorter ($F = 8718.94$; $df = 5, 25$; $MSE = 0.1$; $p<0.0001$) on *R. Padi* (10.2±0.08) and longest on *D. noxia* (12.1±0.08). The total eggs produced were higher ($F = 25648.0$; $df = 4, 24$; $MSE= 3.6$; $p<0.0001$) when *C. lunata* was fed with *R. padi* (740.1±3.00) and lowest on *D. noxia* (203.0±3.23). *A. variegata* exhibited nearly a similar trend whereby the total eggs produced were highest ($F = 4987.08$; $df = 4, 24$; $MSE = 5.5$; $p<0.0001$) on *R. padi* (1655.4±4.83) and lowest on *D. noxia* (244.2±4.69). The two predators coccinellid species *C. lunata* and *A. variegata* are deemed to be efficient predators of *R. padi*, *M. dirhodum* and *S. avenae* and poor on *D. noxia* and *S. graminum*.

Key words: Biocontrol, prey suitability, biology, *Adonia variegata*, *Chelomenes lunata*

INTRODUCTION

Different cereal aphid species occur on wheat fields causing serious yield losses through their direct and indirect damage (Ehsan-ul-Haq, 2003; Nyaanga *et al*., 2006; Van Emden and Harrington, 2007; Lapierre and Hariri, 2008). Both the direct and indirect damage caused by aphids is usually proportional to their numbers on host plants. High aphid numbers also increase crowding which is an important stimulus for wing production (Muller *et al*., 2001; Braedle *et al*., 2006) and eventual dispersal within and between plants. Reduction in aphid numbers will therefore not only reduce pest damage but also indirectly reduce their local and long distance dispersal to other wheat crops.

Practices that reduce the net population of aphids on crops include the use of natural enemies. Natural enemies are the foundation for Integrated Pest Management (IPM) and the core of sustainable agriculture (Dufour, 2001). *Aphidophagous coccinellids* have been found to play a significant role in reducing aphid populations (Olmez Bayhan *et al.*, 2006; Mari *et al.*, 2005). They have been studied worldwide for integration with biological aphid control systems (Irshad, 2001; Pell and Vandenberg, 2002). The coccinellid species *Chelomenes lunata* (Fabricius) and *Adonia variegata* (Goeze) are the most predominant species that were observed preying on cereal aphids in selected wheat growing areas of Kenya (Nyaanga *et al.*, 2008). However, their feeding preference was not investigated.

Prey preference has been observed for several insect predators and has been identified as a species specific characteristic (Venzon *et al.*, 2001). Coccinellid species *Serangium parcesetosum* has been reported to depict significant differences in their preference for different prey species offered (Al-Zyoud, 2007). According to Dixon (2000), the suitability of different prey for a natural enemy development and survival can vary tremendously within all possible host ranges. Rana *et al.* (2002), also reported that the larvae of the generalist ladybird beetle predator *Adalia bipunctata* performed better when reared on the pea aphid *Acyrthosiphon pisum* than on the black bean aphid *Aphis fabae*. Studies on prey suitability for a natural enemy are key steps to evaluate the potential of the organism being used in biological control programmes for insect pests. In this study, prey consumption, growth, development and reproductive parameters of two aphidophagous coccinellid species *C. lunata* and *A.variegata* were measured to quantify the suitability of five aphid prey species *Schizaphis graminum* (Rondani), *Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (Linnaeus), *Sitobion avenae* (Fabricius), *Diuraphis noxia* (Kurdjumov) in the laboratory.

MATERIALS AND METHODS

Materials: The experiments were carried out in 2008 at Egerton University situated in the Rift valley province of Kenya. The five cereal aphid species; *S. graminum, M. dirhodum, R. padi, S. avenae* and *D. noxia* used in the experiments as prey, were collected from farmers' wheat fields around Egerton University. They were reared as a mixed populations maintained on potted wheat plants placed in Plexiglass cages measuring 90×60×60 cm. The cages were kept in the greenhouse at 12 h light/12 h dark cycle, a temperature of 25±1°C and 65±5% RH. Fresh potted wheat plants were placed in the cages twice a week to replace the deteriorating ones.

Methods: To obtain the desired stages of coccinellid beetles, *A. variegata* and *C. lunata* female and male adults were collected from the experimental farm at Egerton University. The beetles were paired (male and female) and the two species were separately introduced into the cages containing the well established mixed colonies of aphid prey. Fresh supplies of aphid prey were placed in the cages after every five days to ensure that the beetles had a continuous supply of food. Once oviposition began, males were removed so that females could oviposit in isolation. The newly deposited eggs were incubated under the same conditions.

To determine the effect of different cereal aphid prey species on the growth and development of the immature connellid predators, an experiment was conducted in the laboratory using a completely randomized plot design replicated five times. The experimental conditions were 12 h light/12 h dark, a temperature of 23±1°C and 60±5% RH. Wheat leaf sections were inserted in moist sand placed at the periphery of petri dishes (12×1.5 cm). Five 3rd instar aphids from each of the five test aphid species were collected from the stock cultures. The different species were separately settled on the wheat leaf sections. One petri dish containing only moist sand was placed in each rep as a control unit. One newly hatched coccinellid species *C. lunata* larvae was placed in each of the petri dishes. The same experimental set up was repeated for coccinellid species *A. variegeta* larvae. The larvae were supplied with aphids settled on fresh wheat leaf sections as frequently as possible. Individual coccinellid larvae were checked twice daily for ecdysis and survivorship. The exuviae were counted to determine molting. The larval weight increase was also taken after every two days until pupation.

Effect of aphid species on coccinellid adults' development and reproduction: To determine the effect of different cereal aphid prey species on the development and reproduction of the adult connellid predators, an experiment was conducted in the laboratory using a completely randomized plot design replicated five times. Five adult coccinellid species *C. lunata* female beetles emerging on the same day were collected from greenhouse cultures and weighed before being starved for 24 h. The beetles were singly placed in petri dishes. Fifty third instar aphids from each of the test aphid species was introduced into the petri dishes containing the beetles. This was repeated for coccinellid species *A. variegata*. The number of aphids consumed after the first 24 h was quantified by counting those remaining in the petri dish. The female beetles were paired with mature males marked on the right elytra with a white marker for better tracking. The beetle pairs were separately offered unlimited supply of the different test aphid species. The parameters measured in this experiment included; Pre-oviposition period (period from adult emergency to when the first set of eggs were laid), oviposition period (period from the time the first set of eggs were laid until no more eggs were produced or the beetle died. Egg production by females during an experiment was quantified by checking petri dishes three times each day (day time). Eggs were counted and removed at each check. The average eggs per day and total eggs were determined.

Data analysis: The data was analyzed using a one-way analysis of variance (ANOVA); means were separated by LSD at 0.05 level using the statistical package software (SAS, 2002).

RESULTS

Coccinellids larval growth and development on different aphid species: The body weight of the immature stages differed significantly after feeding on the different cereal aphid species. *C. lunata* larvae feeding on *S. graminum* and *D. noxia* recorded significantly low weights (4.6±0.19 and 3±0.26) mg, respectively within the first six days compared to *M. dirhodum*, *R. padi* and *S. avenae* which recorded 6.9±0.10, 6.7±0.19 and 6.5±0.17 mg, respectively (Fig. 1a). The larvae feeding on *M. dirhodum* however, recorded a significantly higher weight (14±0.15) mg by the 12th day which was also the last day to pupation, compared to *R. padi* which recorded (13.3±0.22) mg and *S. avenae* (13±0.20) mg and also pupated on the same day. The weights were different for the *C. lunata* larvae feeding on *S. graminum* (8±0.18) and *D. noxia* (7.5±0.18 mg). The larvae feeding on *S. graminum* pupated on the fourteenth day weighing 9.8±0.22 mg while those on *D. noxia* pupated on the sixteenth day weighing 8.8±0.26 mg. On the other hand, the newly hatched *A. variegata* larvae feeding on *M. dirhodum* recorded no significant differences in weight (9.9±0.13) mg by the tenth day compared to *R. padi* (9.1±0.23) mg and *S. avenae* (9.5±0.0.48) mg, all pupating on the same day (Fig. 1b). *S. graminum* and *D. noxia* recorded significantly low weights (7.7±0.23 and 7±0.32) mg, respectively on the same tenth day. The larvae feeding on *S. graminum* and *D. noxia* however, pupated on the twelfth day with significant differences in their weights (8.3±0.25 and 7.5±0.31) mg, respectively.

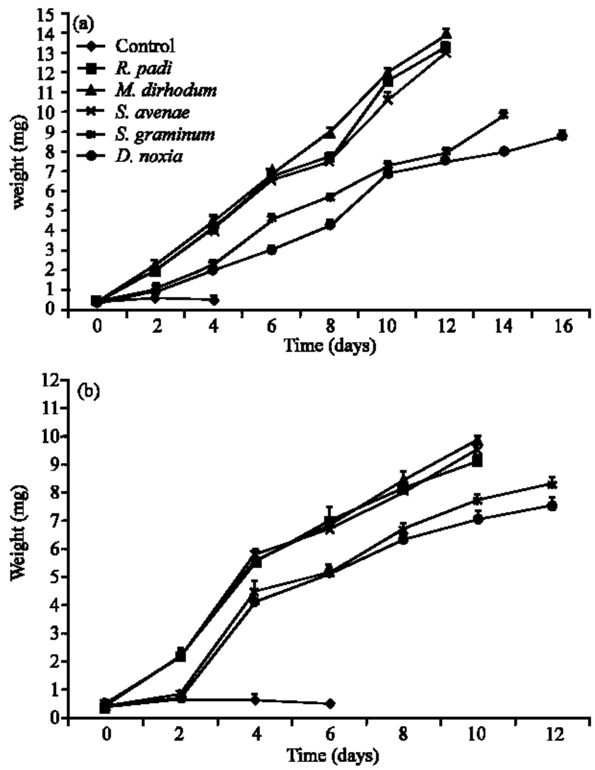

Fig. 1(a-b): Coccinellid species (a) *C. lunata* and (b) *A. variegata* larval weight increase on different cereal aphid prey species

The five cereal aphids exhibited considerable variation with respect to their effect on the average duration of first, second, third and fourth instar larvae for the two predators tested. In the case of *C. lunata*, the duration of first instar was not significantly different among the aphid species tested (F = 0.8; df = 5, 29; p>0.56) (Table 1). The duration of the second instar was however shortest when larvae consumed *R. padi* than *M. dirhodum* and *S. avenae* which were similar, followed by *S. graminum*. The duration was significantly longer on *D. noxia* (F = 273.95; df = 4, 24; p<0.0001). The duration of the third instar was similar when larvae on consumed *R. padi, M. dirhodum* and *S. avenae* but longer on *S. graminum* and *D. noxia* (F = 116.02; df = 4, 24; p<0.0001). Similarly, the fourth instars took a shorter time to develop on *R. padi* than *M. dirhodum* and *S. avenae* which were similar and longest on *S. graminum* which was not significantly different from *D. noxia* (F = 695.9; df = 4, 24; p<0.0001). On the other hand the duration of *A. Variegata* first instar larvae was shortest on *R. padi* than *M. dirhodum* and *S. avenae* which were similar and longest on *S. graminum, D. noxia* which was not significantly different from the control (F = 61.49; df = 5, 29; p<0.0001) (Table 1). The duration of the second instar was shortest when the larvae consumed *R. padi* than *M. dirhodum* and *S. avenae* which were similar, followed by *S. graminum* and longer on *D. noxia* which was not significantly different from the control (F = 32.4; df = 5, 29; p<0.0001). The duration of the third instar was similar when larvae consumed *R. padi* and *M. dirhodum,* followed by *S. avenae* ,then *S. graminum* but longer on *D. noxia* (F = 314.12; df = 4, 24; p<0.0001). The fourth instars took a similar time to develop on *R. padi, M. dirhodum* and *S. avenae* similar and longest on *S. graminum* which was not significantly different from *D. noxia* (F = 695.9; df = 4, 24; p<0.0001).

Table 1: Developmental period of larval stages of *C. lunata* and *A. variegata* fed on five cereal aphid prey species

	Developmental period (Mean±SE in days)*				
Aphid species	1st instar	2nd instar	3rd instar	4th instar	Total
C. lunata					
Control	3.0	-	-	-	-
R. padi	3.0	3.0±0.08d	3.0±0.04b	2.7±0.13d	11.7±0.14e
M. dirhodum	3.0	3.1±0.13c	3.0±0.04b	3.0±0.04c	12.1±0.20d
S. avenae	3.0	3.4±0.10c	3.2±0.15b	3.0±0.10c	12.6±0.15c
S. graminum	3.0	3.7±0.19b	4.1±0.37a	4.2±0.15a	15.0±0.40b
D. noxia	3.0	4.5±0.09a	4.2±0.11a	4.5±0.04a	16.2±0.07a
LSD (0.05)	NS	0.0446	0.2475	0.1165	0.23
A. variegata					
Control	2.8±0.04a	3.0±0.04a	-	-	-
R. padi	2.5±0.05c	2.5±0.05d	2.5±0.04d	2.7±0.04b	10.2±0.08e
M. dirhodum	2.6±0.04b	2.6±0.11c	2.5±0.08d	2.7±0.04b	10.4±0.04d
S. avenae	2.6±0.08b	2.7±0.05bc	2.6±0.07c	2.7±0.08b	10.7±0.10c
S. graminum	2.8±0.05a	2.8±0.05b	2.9±0.04b	3.1±0.05a	11.6±0.04b
D. noxia	2.8±0.08a	2.9±0.04.a	3.2±0.05a	3.2±0.07a	12.1±0.08a
LSD (0.05)	0.0446	0.0808	0.0769	0.0769	0.1319

Means followed by the same letter in the same column are not significantly different from each other as per the Least Significant Difference (LSD α = 0.05). *Time taken from one instar to the other

The total larval developmental period of coccinellid species *C. lunata* feeding on the different aphid species varied from 11.7 to 16.2 (Table 1). The period was significantly shorter when they were fed on *R. padi* (11.7±0.14), *M. dirhodum* (12.1±0.20) and *S. avenae* (12.6±0.15) days, medium length on *S. graminum* (15.0±0.40) and longest on *D. noxia* (16.2) days ($F = 1408$; df = 4, 24; $p<0.0001$). The total larval developmental period of coccinellid species *A. variegata* feeding on the different aphid species varied from 10.2 to 12.2 (Table 1). The total larval developmental period for *A.variegata* was significantly shorter for *R. Padi* (10.2±0.08), *M. dirhodum* (10.4±0.04) and *S. avenae* (10.7±0.10) days followed by *S. graminum* (11.6±0.04) days and longest on *D. noxia* (12.1±0.08) days ($F = 8718$; df = 4, 24; $p<0.0001$). The longevity of starving larvae (control) was 4 days for *C. lunata* and 6 days for *A. variegata*. When fed on the different aphid species all larvae survived to the pupal stage.

Prey consumption: *C. lunata* adults consumed more aphids within their first 24 h of feeding when fed on *M. dirhodum* (33.0±0.22), followed by *R. Padi* (28.7±0.51), *S. avenae* (25.7±0.22), *S. graminum* (21.4±0.53) and the least was *D. noxia* (18.1±0.25) ($F = 1208.29$; df = 4, 24; $p<0.0001$). The trend was similar for *A. variegata* adults which recorded 22.3±0.11 for *M. dirhodum*, followed by *R. Padi* (22.1±0.08), *S. avenae* (21.7±0.19), *S. graminum* (18.9±0.11) and the least was *D. noxia* (16.0±0.27) ($F = 1288.80$; df = 4, 24; $p<0.0001$) (Table 2).

Effect of different aphid species on coccinellids reproductive performance: The five cereal aphids also exhibited differences in their effect on the reproductive parameter of the two predators. For *C. lunata*, pre-oviposition period was shortest on *R. padi, M. dirhodum* and *S. avenae* and longest on *S. graminum* and *D. noxia* ($F = 3.89$; df = 4, 24; $p<0.01$). Oviposition period was longest on *R. padi*, followed by *M. dirhodum* and *S. avenae* then *S. graminum* and last came *D. noxia*

Table 2: Mean number of aphid prey species consumed within the first 24 h by *C. lunata* and *A. variegata* adults

	No. of aphids consumed during the first 24 h	
Aphid prey species	*C. lunata*	*A. variegata*
R. padi	28.7±0.51b	22.1±0.08b
M. dirhodum	33.0±0.22a	22.3±0.11a
S. avenae	25.7±0.22c	21.7±0.19c
S. graminum	21.4±0.53d	18.9±0.11d
D. noxia	18.1±0.25e	16.0±0.27e
LSD (0.05)	0.50	0.2231

Means followed by the same letter in the same column are not significantly different as per the Least Significant Difference at α = 0.05

Table 3: Pre-oviposition, oviposition, mean number of eggs per day and total eggs of coccinellid species *C. lunata* and *A. variegata* adult fed on five cereal aphid prey species

	Time in days		Reproduction	
Aphid species	Pre-ovip	Ovip	Av. egg/day	Fecundity
C. lunata				
R. padi	5.2±0.17b	75.9±2.83a	9.8±0.37a	740.1±3.00a
M. dirhodum	5.2±0.14b	69.6±2.70b	9.8±0.16a	677.4±3.79b
S. avenae	5.2±0.14b	66.4±4.40b	9. 7±0.71a	647.4±4.21c
S. graminum	6.7±0.05ab	60.2±2.97c	4.0±0.20b	240.6±3.82d
D. noxia	7.5 ±0.30a	52.4±2.29d	3.9±0.20b	203.0±3.23e
LSD (0.05)	2.80	3.84	0.51	4.75
A. variegata				
R. padi	3.8±0.13d	51.2±0.83b	12.8±0.21a	655.4±4.83a
M. dirhodum	3.9±0.10cd	51.0±1.67b	12.9±0.39a	656.2±4.15a
S. avenae	4.1±0.26c	55.5±1.72a	10.9±0.32b	601.8±6.10b
S. graminum	4.9±0.19b	49.2±0.98b	9.3±0.26c	459.7±7.36c
D. noxia	5.2±0.15a	45.3±1.57c	5.4±0.12d	244.2±4.69d
LSD (0.05)	0.23	2.05	0.44	7.32

Means followed by the same letter in the same column are not significantly different as per the Least Significant Difference at α = 0.05

($F = 47.8$; df = 4, 24; $p<0.0001$) (Table 3). The average number of eggs laid per female per day was highest on *R. padi, M. dirhodum* and *S. avenae* and lowest on *S. graminum* and *D. noxia* ($F = 338.6$; df = 4, 24; $p<0.0001$). Similarly the total eggs produced remained highest when *C. lunata* was fed with *R. padi*, *S. avenae* and *M. dirhodum* and lowest when fed on *S. graminum* and *D. noxia* ($f = 25648.0$; df = 4, 24; $p<0.0001$). *A. variegata* also exhibited nearly a similar trend (Table 3). Pre-oviposition period was shortest on *R. padi* and *M. dirhodum* followed by *S. avenae* and then *S. graminum* and the longest was on *D. noxia* ($F = 62.19$; df = 4, 24; $p<0.0001$). Oviposition period was longest on *S. avenae* followed by *R. padi* and *M. dirhodum* then *S. graminum* and the shortest was *D. noxia* ($F = 28.11$; df = 4, 24; $p<0.0001$). The average number of eggs laid per female per day was highest on *R. padi* and *M. dirhodum* followed by *S. avenae* then *S. graminum* and lowest on *D. noxia* ($F = 424.83$; df = 4, 24; $p<0.0001$). Similarly the total eggs produced remained highest when *A. variegata* was fed with *R. padi* and *M. dirhodum* followed by *S. avenae* then *S. graminum* and lowest on *D. noxia* ($F = 4987.08$; df = 4, 24; $p<0.0001$). *A. variegata* indicated better reproductive performance in all aphid prey species tested compared to *C. lunata*.

DISCUSSION

Growth, development and reproduction of the two coccinellid predators *C. lunata* and *A. variegata* were closely associated with the aphid prey species offered. This is consistent with studies done by Ali and Rizvi (2007), who observed that the development and predatory response of coccinellid species *Coccinella septempunctata* was better on aphid species *Lipaphis erysimi* compared to *Aphis craccivora*, *Hyadaphis coriandri*, *Rhopalosiphum nymphae* and *Macrosiphum rosae*. Dixon (2000) also reported that some coccinellids do better when they feed on certain species of prey compared to others. Prey quality has been found to influence the development, survival and reproduction of coccinellids (Zhang *et al*., 2007). Fast larval growth and shortened developmental durations were observed in our study when the two predators were fed with *R. padi*, *M. dirhodum* and *S. avenae*. This may not only increase the fitness of the subsequent adult population but also impart positively on future coccinellid population build up and ultimately their efficacy as biological control agents.

When considering prey consumption, *R. padi*, *M. dirhodum* and *S. avenae* seemed much more palatable and attractive to both predators compared to *D. noxia* and *S. graminum*. Inayat *et al*. (2011) however, reported that *S. graminum* was the preferred species for both adult and larval coccinellid species *Coccinella septempunctata*, *C. sexmaculata* and *A. variegata* when compared to the aphid species *Macrosiphum miscanthi*, *Aphis maidis* and the jassid *Empoasca kerri*. The likely explanation for this could be that most coccinellids being generalist predators, there preference is likely dependent on what is on offer. Coccinellids have been observed to continue feeding even when they encounter unsuitable prey but with detrimental effects (Obrycki *et al*., 1997).

The two predators in our study indicated shorter pre-oviposition and longer oviposition period when they were fed with *R. padi*, *M. dirhodum* and *S. avenae*. However Abdel-Salam (2000) observed no differences in survivorship and developmental rates in coccinellid species *Harmonia axyridis* reared on a non-aphid diet consisting of the grain moth *Sitotroga cerealella* eggs and those reported for aphid diets. Coccinellids tend to include other insect prey in their diet probably due to shortages of preferred aphidophagous prey (Sloggett and Majerus, 2000) or in some cases due to the benefits of meeting nutritional requirements. Gagne *et al*. (2002) also found that *Coleomegilla maculata* first instars preferred conspecific eggs over aphids and the reason was that the eggs were nutritionally superior to aphids as food.

The high average and total egg numbers observed when the beetles were fed with *R. padi*, *M. dirhodum* and *S. avenae* compared to *D. noxia* and *S. graminum* is consistent with observations made by Kalushkov and Hodek (2004). They reported that females of coccinellid species *C. septempunctata* laid twice as many eggs when they were fed with the aphid species *Aphis pisum* and *S. avenae* compared to *A. fabae* and *A. craccivora*. Suboptimal prey diet as might be the case with *D. noxia* and *S. graminum* in this study can impart negative effects that include reduced rates of development, reproduction and survival (Albuquerque *et al*., 1997). *D. noxia* and *S. graminum* contain toxins which they inject into the plant while feeding. These aphid species are able to alter the amino acid profile of phloem contents in susceptible wheat for their own benefit (Petersen and Sandstrom, 2001). It is not clear in this study however, whether *D. noxia* and *S. graminum* are poor prey for the two coccinellid species tested because they are of low nutritional quality or they contain toxins that are detrimental to the predator.

Coccinellid species *A. variegata* larvae maintained a fairly high growth rate when feeding on the less prefered prey species (*S. graminum* and *D. noxia*) compared to *C. lunata*. There was however little indication from the study that either of the two predators was more effective at exploiting cereal aphids than the other. This is further supported by the fact that although *C. lunata* adults consumed 48% more aphids than *A. variegata* when feeding on the most prefered prey for both predators (*M. dirhodum*), this did not result in greater average daily egg production by the former.

CONCLUSION

This study has concluded that aphid prey species had a substantial effect on the life history of both coccinellid species *C. variegata* and *C. lunata*. The differential growth, development and reproduction of the coccinellid predator when fed on different cereal aphids are an indication of how crucial aphid species are when considering coccinellids for biological control. The two coccinellid species in this study can therefore be deemed to be efficient predators of *R. padi, M. dirhodum* and *S. avenae* and poor on *D. noxia* and *S. graminum*. The study therefore suggests that coccinellids be combined with other components of IPM so as to sufficiently manage cereal aphid populations on wheat.

ACKNOWLEDGMENTS

Author thank Egerton University and African Institute for Capacity Development (AICAD) for the financial support of this research which was part of a larger project.

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